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FORT KNOX, KENTUCKY

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A FIELD STUDY OF RIFLE AIMING STEADINESS AND SERIAL REACTION PERFORMANCE AS AFFECTED BY THERMAL STRESS AND ACTIVITY*

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*Subtask under Psychophysiological Studies, AMRL Project No. 6-95-20-001, Subtask, Climatic Effects on Psychophysiological Abilities.

RESEARCH AND DEVELOPMENT DIVISION
OFFICE OF THE SURGEON GENERAL
DEPARTMENT OF THE ARMY

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A FIELD STUDY OF RIFLE AIMING STEADINESS AND SERIAL REACTION PERFORMANCE AS AFFECTED BY THERMAL STRESS AND ACTIVITY*

by

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ABSTRACT

A FIELD STUDY OF RIFLE AIMING STEADINESS AND SERIAL REACTION PERFORMANCE AS AFFECTED BY THERMAL STRESS AND ACTIVITY

OBJECT

Two aspects of psychomotor behavior, rifle aiming steadiness and serial reaction performance, were studied under conditions of cold stress (at Fort Churchill, Canada) and heat stress (at Yuma, Arizona) in combination with certain exercises in order to determine the effects of such stresses upon skills which are involved in military duties.

RESULTS

Short duration activity (push-ups) in the cold resulted in a significant increase in horizontal tremor. A 2-hour forced march in low ambient temperatures resulted in increased tremor in both the horizontal and vertical dimensions. Heat stress and exercise during heat exposure had no apparent effect on rifle aiming steadiness. Serial reaction time and errors were not affected by heat stress or cold stress, although possible decremental effects which did occur may have been masked by learning effects in this study.

CONCLUSIONS

The differential effects of various types of activity upon horizontal and vertical tremor probably are a result of the particular muscle groups involved in the exercises and the way in which a rifle is held. Serial reaction performance of the type used in this study perhaps is not sufficiently complex to be disturbed by the environmental stresses used here.

RECOMMENDATIONS

Further research on the effects of environmental extremes upon human behavior is indicated. A modification of the serial reaction test used here should be designed and tested in various ambient temperatures.

Submitted 20 January 1956 by:

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A FIELD STUDY OF RIFLE AIMING STEADINESS AND SERIAL REACTION PERFORMANCE AS AFFECTED BY THERMAL STRESS AND ACTIVITY

I. INTRODUCTION

Two aspects of psychomotor behavior, rifle aiming steadiness and serial reaction time, were selected for study under 2 extremes of environmental stress, the severe cold encountered at Fort Churchill, Manitoba, Canada, and the dry heat found at Yuma Test Station, Yuma, Arizona. These 2 aspects of behavior were selected on the basis of their relevancy for currently existing psychophysiological problems in the armed forces. Rifle aiming steadiness, insofar as it affects marksmanship, has been a recurring problem in the army for many years. The effects of environmental extremes on this type of behavior apparently have not been investigated previously although Blair (1) investigated steadiness primarily as a function of drug intake in an arctic situation.

The second task selected for this study, serial reaction time, represents a type of fairly complex behavior which has parallels in the operation of several kinds of equipment. The subject is required to make a series of discriminations, each followed by appropriate motor responses, and is asked to do this as quickly and accurately as possible. If environmental extremes affect the speed or accuracy of such performance, the effects should be known so that they may be compensated for in training procedures or in adjustments of the work load imposed upon the operator exposed to such stresses.

II. EXPERIMENTAL

The apparatus used in these studies was designed to meet the rigors of field experimentation, to withstand extremes of temperature and to allow frequent and reliable calibration. In some cases no commercial equipment met these requirements and various components were constructed in the laboratory.

A. Subjects

The subjects used in these studies were male draftees and enlistees who volunteered for test team activities. Their ages ranged from 18 to 35 years. Ten of the subjects served at Yuma and Churchill.

B. Apparatus

1. Rifle Aiming Steadiness Test

The apparatus for the rifle aiming steadiness test (Fig. 1) consisted of a pair of Baldwin-Lima-Hamilton SR-4 strain gages mounted on aluminum bars (18 cm long) attached to the muzzle of an M-1 rifle. The assembly weighed 69 gm, or 1.6% of the total weight (4246 gm) of the unloaded M-1 rifle without sling. Subjects reported that the "feel" of the rifle was not noticeably different from an unmodified rifle.

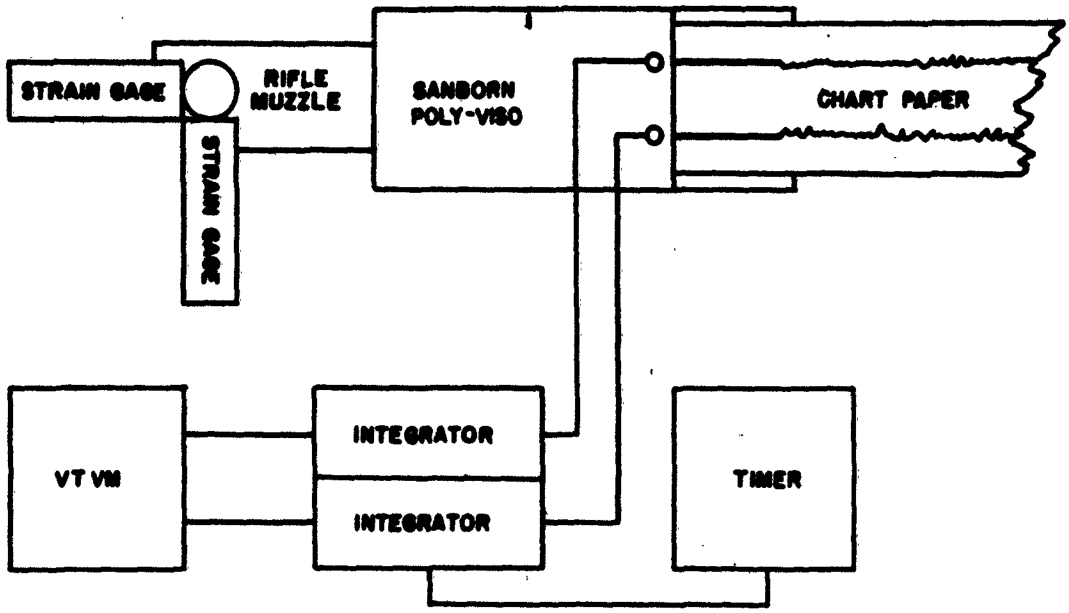

FIG. I BLOCK DIAGRAM OF COMPONENTS OF RIFLE AIMING STEADINESS APPARATUS

The strain gages were activated by the inertia of the aluminum bars; as the rifle moved slightly because of unsteadiness on the part of the subject, the gages were stretched or compressed sufficiently to give a readable signal. It should be emphasized that the rifle was attached in no way to any external apparatus, except through a highly flexible cable leading to the recording system, and that the rifle aiming situation was identical with normal usage of a rifle except for the slight additional weight at the muzzle. One strain gage was placed in the horizontal and one in the vertical plane, thus providing a

measure of tremor in 2 dimensions. The strain gages were fed into a 2-channel Sanborn Poly-Viso Recorder containing 2 strain gage amplifiers. Vertical and horizontal movements were recorded separately on paper tape. The output from the pen motors also was led to a pair of integrators controlled by an electronic timer. The integrators (Fig. 2) were modified versions of the circuit described by Ford (2). The output of the integrator was read as a charge on a capacitor by an RCA Senior Volt-Ohmyst with an input impedance of 11 megohms. The time during which the integration of the records occurred was marked on the Sanborn tapes by a signal marker and was recorded to the nearest .01 second by an experimenter reading a Standard Electric Timer.

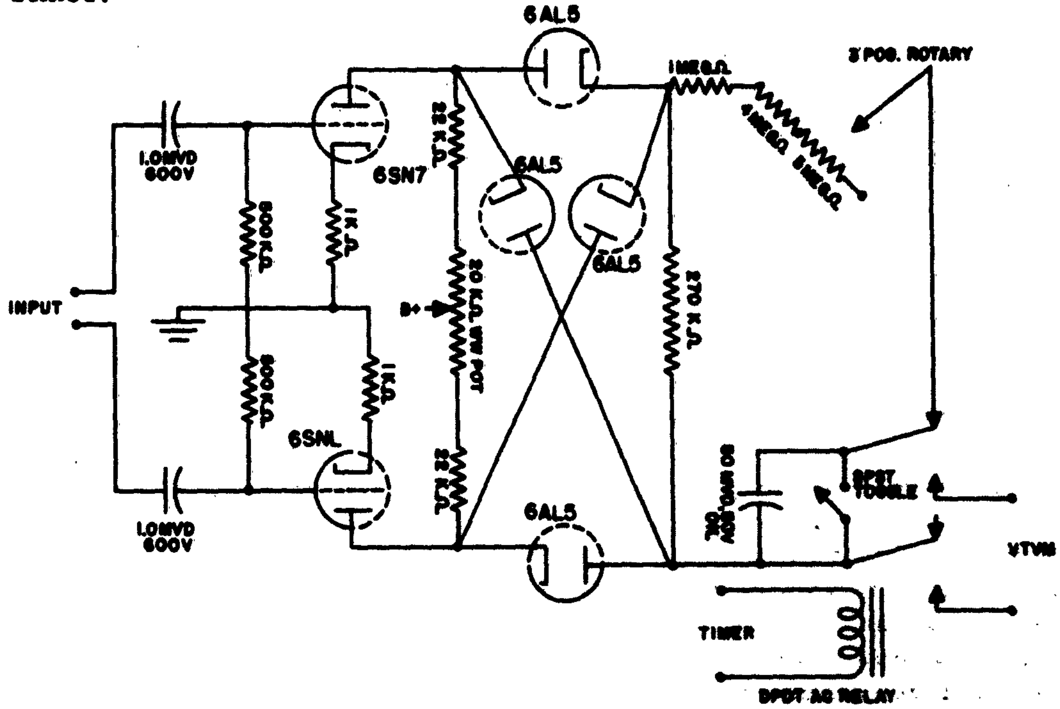

FIG. 2. INTEGRATOR USED IN THIS STUDY; MODIFIED FROM FORD (2)

2. Serial Reaction Test

The apparatus for the serial reaction test was constructed from standard components in the laboratory. It consisted of a set of 4 brass plates, 3 inches by 3 inches, mounted on a board. Over each brass plate was a light in a jewelled socket. The subject held a stylus made of a length of one-eighth inch brass rod inserted into a 1 inch wooden dowel 9.75 inches long. The brass rod protruded 1.75 inches from the end of the dowel. The plates, lights and stylus were connected to a programming and scoring unit which controlled the sequence

of lights appearing on the board, scored the total time required to respond to 49 stimulus presentations and recorded the number of errors made by the subject.

The programmer contained 2 different pre-determined random orders of presentation of the lights, wired into an Automatic Electric Stepping Switch. Additional banks of the stepping switch contained a counting circuit which registered on a Gorrell and Gorrell impulse counter, the total number of contacts between stylus and plates. The subject's task was self-paced. He was instructed to tap the plate over which a light appeared. The tapping of the proper plate turned off the light over that plate and turned on a light over another plate. One trial consisted of 49 such stimulus presentations and responses. The total time (from the time the first light was turned on until the last light was turned off) was recorded together with the total number of taps made by the subject. No record was made of the direction of errors.

C. Methods and Procedure

1. Rifle Aiming Steadiness Test

a. Cold Stress Study at Churchill - Fourteen subjects were given pre-test measures in the rifle aiming steadiness test. The pre-test measures were made in a normally heated building during a morning session, approximately 2 hours after breakfast and following a 1-hour rest period during which the subjects were allowed to sit down, read or play card games and converse freely. The subjects were asked to aim at a disc target from a standing position and to hold their aim until told to relax. Recordings were started approximately one second after the subject was told to hold his aim and were continued for approximately 7 seconds. Two trials were recorded for each subject under each of the conditions. In both trials the horizontal and vertical error was recorded and integrated separately.

In the afternoon following the pre-test measures the subjects were asked individually to exercise vigorously by performing 15 push-ups in rhythm to a rapid count. The exercises were performed in a temperature of -25° F to -30° F with windchill factors ranging from 1900 to 2130 C/m^2/hr. As soon as each subject completed the required number of push-ups he was given 2 trials on the rifle aiming steadiness test in a room which was at approximately the same temperature. The 2 trials required about 25 seconds to perform.

The following day the 14 subjects were given a forced march of 2 hours' duration at 120 paces/minute in an environment of -42° F to -35° F with windchill factors varying from 1960 to 2050 C/m^2/hr. As each subject completed his 2-hour march he was re-tested on the rifle aiming steadiness apparatus as described above. The subjects in all the above procedures were dressed in full arctic gear, except that when they were told to pick up the rifle their mittens were removed.

b. Heat Stress Study at Yuma - Twelve subjects were given pre-test measures as described above. Three experimental treatments were then administered; a series of push-ups, a series of squat-thrusts, and a forced march of 3 hours' duration, each followed immediately by measurements on the steadiness apparatus. The activities were conducted outdoors in temperatures ranging from +97.2° F to +111.2° F. The subjects were dressed in issue fatigue clothing with sun helmets. During the forced march, which was done at the rate of 120 paces/minute, subjects were allowed to stop for 5 minutes each hour in order to drink water.

2. Serial Reaction Test

a. Cold Stress Study - Twelve subjects were exposed in a counterbalanced order to 3 levels of cold stress: normal indoor temperature (+70° F), cold shielded from the wind (-15° F to -24° F), and outdoor exposure (-17° F to -25° F with windchill factors ranging from 1400 to 1910 C/m^2/hr). The exposure to cold environment lasted for one hour after which the subjects were tested on the serial reaction apparatus while the cold exposure continued. The subjects had been instructed in the task previously. They were told to work rapidly but to make as few errors as possible. On another day subjects performed squat-thrusts to a rapid count until they were exhausted. The exercises were performed in temperatures of +8° F to +13° F with windchill factors ranging from 1310 to 1490 C/m^2/hr. Immediately following the fatiguing exercises, the subjects were re-tested on the serial reaction apparatus.

b. Heat Stress Study - Fourteen subjects were given pre-test measures in an airconditioned building at +75° F. Subjects then performed push-ups for approximately 30 seconds and squat-thrusts for approximately 120 seconds, separately and in counterbalanced order. The exercises were conducted in environmental temperatures ranging from +96.1° F to +104.5° F. As soon as the exercises were completed the subjects performed the serial reaction task in approximately the same environmental temperature outdoors.

III. RESULTS

A. Rifle Aiming Steadiness

The effects of thermal and fatigue stress upon rifle aiming steadiness are shown in Figure 3. Short duration activity (push-ups) in the cold resulted in a significant ($P < .01$) increase in horizontal tremor, but produced no significant ($P < .80$) changes in vertical tremor. The tremor resulting from a 2-hour forced march in the cold was increased significantly over pre-test measures in both the horizontal ($P < .001$) and vertical ($P < .02$) dimensions. Under the heat stress condition no significant differences appeared as a result of short duration exercise or a forced march.

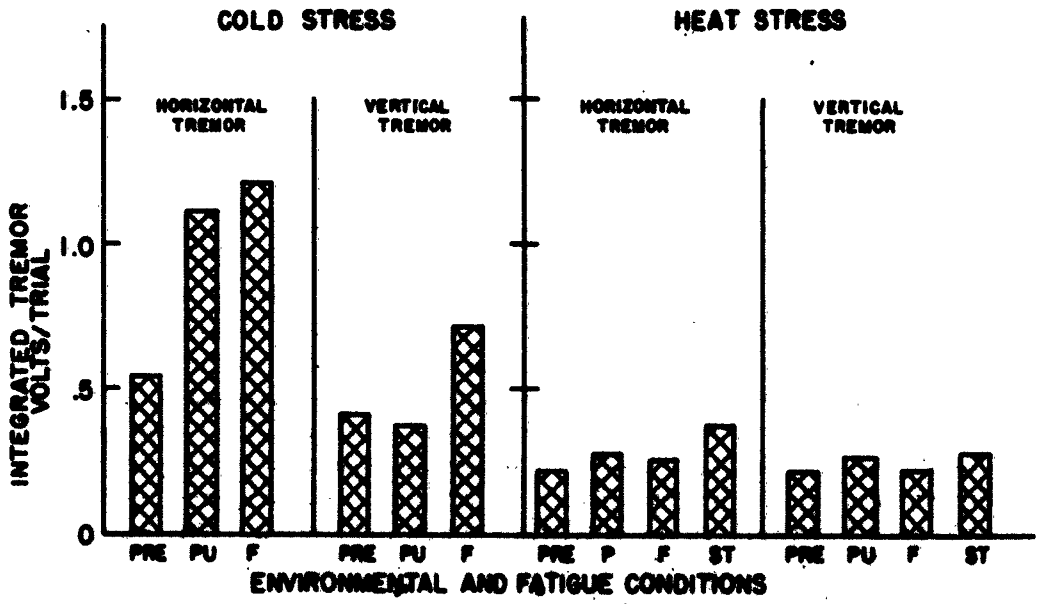

FIG. 3 RIFLE AIMING STEADINESS DURING FATIGUE AND THERMAL STRESS.
PRE: pretest measures. PU: following pushups. F: following forced march. ST: following squat thrusts.

B. Serial Reaction

The mean time scores for each condition of the serial reaction test are shown in Figure 4. No significant differences were found between the 3 levels of low temperature stress but the time score for the fatigue condition was significantly less ($P < .01$) than the scores for the thermal stress conditions. Similarly, no significant differences were found between the pre-test, squat-thrust and push-up measures

performed in the heat, although the post-test score was significantly different from the pre-test ($P < .02$) and the exercise conditions ($P < .01$).

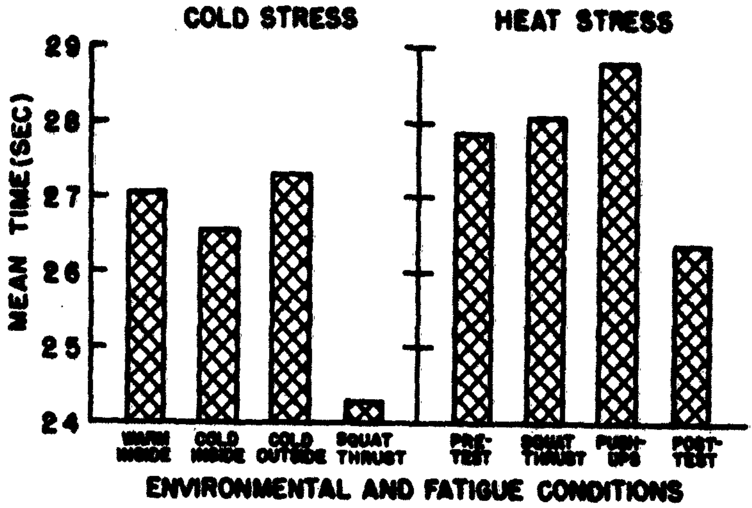

FIG. 4 MEAN TIME REQUIRED FOR SERIAL REACTION TEST FOR EACH ENVIRONMENTAL AND FATIGUE CONDITION

No systematic variations were found in the error scores for the various conditions (Fig. 5).

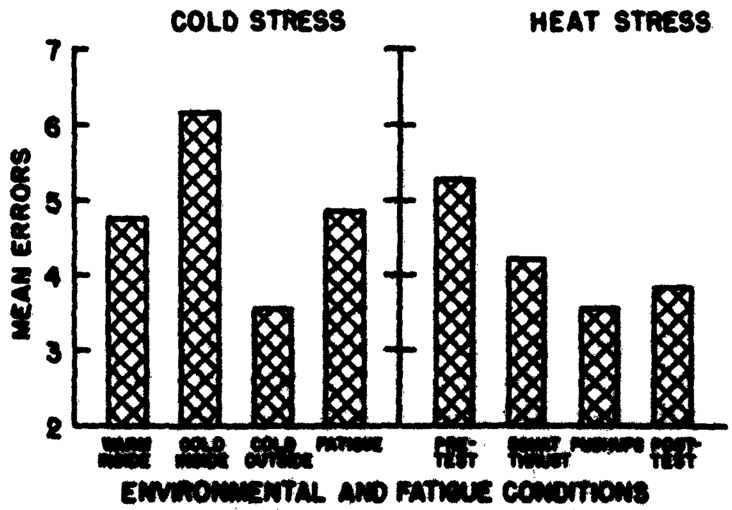

FIG. 5 MEAN ERROR SCORE IN SERIAL REACTION TEST FOR EACH ENVIRONMENTAL AND FATIGUE CONDITION

IV. DISCUSSION AND CONCLUSIONS

Rifle aiming steadiness appears to be affected by both short duration exercise and a 2-hour march in low temperatures. The increased tremor under cold stress conditions noted in this study is a decrease in steadiness, not the result of shivering. Subjects were observed carefully during the experiments in order to detect any indications of shivering. Records of shivering subjects not taking part in the experiment were examined; the record of shivering is entirely different in wave form and amplitude from the low-amplitude tremor observed here. The differential amount of tremor in the horizontal and vertical dimensions probably was an effect of the manner in which the rifle was held. This contention is supported by the fact that push-ups, which fatigue certain muscles of the shoulder girdle (3), affect horizontal and vertical tremor differently. It is possible that a measure of steadiness using a hand-held stylus, as is traditionally done, would not reflect the differences noted here.

Rifle aiming steadiness appeared to be unaffected by exercise during heat exposure.

The results of the serial reaction test are difficult to interpret consistently. There was no obvious effect of thermal stress upon this type of behavior, although certain trends may be noted in the data. The very low time score following the fatiguing exercise is anomalous, but is likely the result of learning. The 3 thermal stress conditions were administered in counterbalanced order, but the fatiguing exercise was given as the last trial for each subject. Learning effects, therefore, are concentrated in this measure instead of being distributed as in the preceding 3 conditions and would tend to lower the mean score.

The heat stress situation permits a partial evaluation of this explanation, since both pre-test and post-test measures were taken. There was a significant difference between the 2 sessions indicating the operation of a learning factor. It is suggested that the scores of trials following exercises in the heat were reduced somewhat from their true values because of the gradual decline in time required for the task as a function of learning. If this explanation, which is difficult to test statistically, is true, then the effects of exercise under heat probably would be significant.

It is likely that the task used in this study was not sufficiently complex to be disturbed by the rather mild stresses used. If the choices in the serial reaction test were increased to perhaps 10 or 12,

and if finer discriminations of the signals were required, it is probable that decrements in performance would be noted more easily.

V. RECOMMENDATIONS

Further research on the effects of environmental extremes upon human behavior is indicated. The serial reaction test appears to have promise for future research, if the subject's task can be made sufficiently complex. It is recommended that such an apparatus be constructed and tested in various ambient temperatures.

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